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EARTH PHOTOGRAPHY FROM  
HIGH-ALTITUDE BALLOONS

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# EARTH PHOTOGRAPHY FROM HIGH-ALTITUDE BALLOONS

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## SUMMARY

Large-area photographs of the earth have been obtained from high-altitude balloon platforms. Some of the photography was coordinated with ground investigations for experimental purposes. The usefulness of large-area photographs and unique photographic formats is evaluated. Certain advantages and disadvantages of free-flight balloons as remote sensing platforms are discussed. Two appendixes detail the camera system and camera-package design.

## INTRODUCTION

Earth-looking photographic experiments were conducted from two high-altitude balloons launched from NASA Wallops Station on August 7, 1969, and August 13, 1969. The experiments were conducted by NASA Langley Research Center (LRC) in cooperation with researchers from the Virginia Institute of Marine Science, Gloucester Point, Va.; U.S. Naval Oceanographic Office, Washington, D.C.; and U.S. Department of the Interior, Geological Survey, Washington, D.C. A third mission (not coupled to surface experiments) was flown from Holloman Air Force Base, New Mexico, on September 25, 1969. The Holloman flight was a short-notice, space-available opportunity and was flown primarily to study operations in such quick-response situations.

The availability of payload space on the LRC two Air Retrieval of Research Payloads balloons to be launched from Wallops Station provided the initial stimulus for the earth-photography experiments. The economical attractiveness of these vehicles of opportunity was augmented by the chance to obtain the first small-scale (large-area) photography of important coastal features in this region.

In addition to conducting the photographic experiments, LRC hoped the flights would provide information on the performance and usefulness of balloon platforms for remote sensing applications. The three flights are believed to have been the first remote sensing experiments associated with the study of earth resources to be conducted from high-altitude free-flight balloons.

The purposes of this report are to code and identify the photography from the three flights and to provide mission information related to the experiments. The report also describes the camera system (appendix A) and package (appendix B). Principal measurements and calculations were made in the U.S. Customary Units but are given in the International System of Units (SI).

Information for obtaining this photography should be directed to  
Technology Application Center  
University of New Mexico, Box 181  
Albuquerque, New Mexico 87106

## NASA WALLOPS STATION EXPERIMENTS

### Investigators and Objectives

Four investigators participated in the first two balloon experiments flown from the NASA Wallops Station site.

(1) Maynard M. Nichols (Virginia Institute of Marine Science) was interested primarily in observing near-shore turbid patterns resulting from sediment runoff and tidal action. The balloon would hopefully provide a platform from which to observe such phenomena during long segments of the tidal cycle.

(2) Willard E. Vary (U.S. Naval Oceanographic Office) had been involved in the development and application of a special blue-insensitive water and haze penetration color film. The balloon flight afforded the opportunity for the first high-altitude application of that film.

(3) Raymond W. Fary, Jr. (U.S. Geological Survey), who is Chief of the Remote Sensing Evaluation and Coordination Staff of the Earth Resources Observation Satellite Program, coordinated the research objectives of the hydrology and geography investigators. The primary interest of these investigators was to obtain a photographic simulation of the spectral quality of the return-beam vidicon-camera system scheduled for the Earth Resources Technology Satellites - A and B.

(4) Richard R. Anderson (U.S. Geological Survey and American University) hoped to compare the small-scale color infrared photography from the balloon flights with larger scale, lower altitude coverage obtained during previous investigations in the study of local marshland ecosystems.

Observations were made from a NASA Wallops ship, Range Recoverer, and from a NASA Wallops helicopter equipped with floats. Nichols and NASA coordinated this supporting "ground truth" program. Water samples taken along the earth track of the balloon

flightpath were analyzed by Nichols at the Virginia Institute of Marine Science and the analyses forwarded to the other researchers.

### Film-Filter and Exposure Selections

The film-filter combinations and exposure settings used in the two Wallops Station flights are shown in table I.

### Flight 1

The first balloon was launched by a U.S. Air Force Cambridge Research Laboratory team from NASA Wallops Station at 0540 EDT, August 7, 1969. The photographic mission started at 0645 EDT, the cameras being operated by ground command. The taking and the spacing of pictures were governed by such factors as geographical position, altitude, image overlap, ground-truth sampling operations, and the continuous updating of wind conditions, flight operations, and projected mission termination.

Twenty-six pictures per camera were taken between 0645 and 0928 EDT as the prevailing easterly winds above 20 km carried the balloon on a westerly course across Virginia's "Eastern Shore" and Chesapeake Bay. Most of these photographs were taken from about 30 km, at which altitude the ground coverage on each photograph is approximately 1260 km<sup>2</sup>.

The balloon flight was terminated at 0930 EDT, but an additional 43 pictures per camera were taken during parachute descent. Intermittent photographs taken during this period provided a vertically "telescoped" or "nested" record of the same geographical area as the parachute dropped from 30.5 km to 9.15 km, where the film was finally expended. This unique sequence, which exhibits a 3-to-1 increase in scale and corresponding improvement in resolution, suggests a useful format for interpreting low-resolution spacecraft imagery in earth-survey applications. Selected photographs from the nested sequence are shown in figure 1. The camera package was recovered undamaged in about 30 cm of water.

The Kodak Ektachrome Infrared Aero Film, Type 8443, and the Kodak Ektachrome MS Aerographic Film (ESTAR Base), Type 2448, were processed at Langley Air Force Base and sent to Data Corporation, Dayton, Ohio, for duplication. The color infrared photography exhibited good contrast and resolution. The Ektachrome MS Aerographic Film (ESTAR Base), Type 2448, however, was affected by the prevailing heavy haze conditions and produced rather low-contrast imagery.

Incorrect exposure settings had been inadvertently established for the GAF 1000 Blue-Insensitive Color Film, Type 2575, and for the GAF Anscochrome D/500 Gafstar

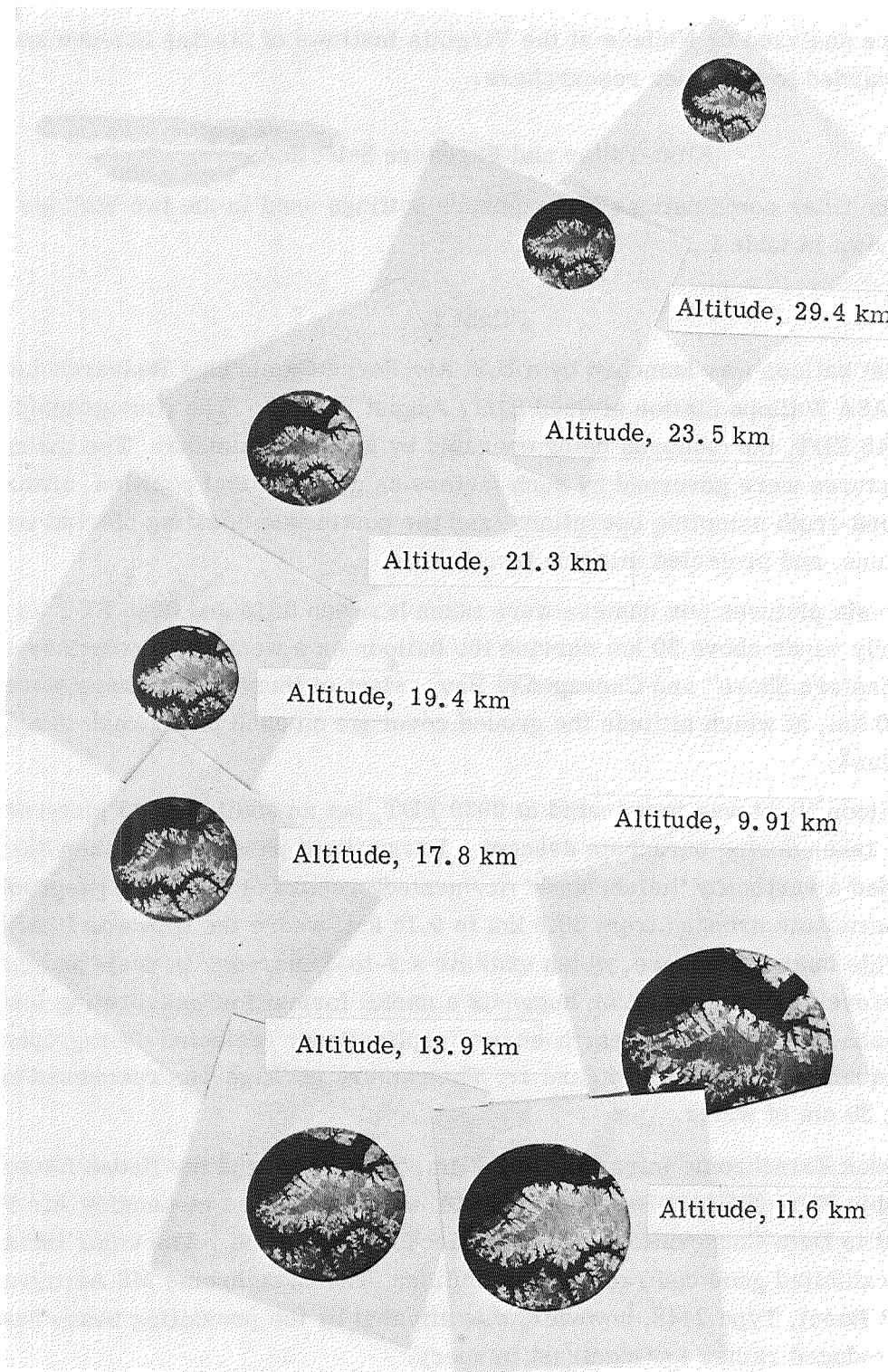


Figure 1.- Vertically nested photographic sequence from flight 1. L-70-3163.1

Color Aerial Film, Type 7550. The resulting overexposed photography was not considered useful and the films were not duplicated.

Shipboard ground-truth water sampling, and turbidity and meteorological observations were made from the NASA Wallops Range Recoverer on the ocean side of Virginia's Eastern Shore. These shipboard measurements were made approximately 1 hour after overflight, the delay being caused primarily in positioning of the ship along the flight path of the balloon. Similar ground-truth measurements were made in Chesapeake Bay from a hovering helicopter 4 hours after overflight.

## Flight 2

The weather outlook for the second balloon flight indicated that the prevailing southwesterly winds below 18 km would very likely carry the balloon up along the coast rather than on a preferred easterly course at these lower altitudes. These wind profiles would make it impossible during the later part of the flight to redirect the balloon back over the ocean for recovery after coming inland on the westerly leg. Thus, it was obvious from the outset that the mission would be subjected to an early termination.

The balloon was launched at 0631 EDT, August 13, 1969. The photographic mission started at 0646 EDT at an altitude of approximately 2.1 km. The first 21 pictures were taken over land areas; after that, the balloon was carried out over the Atlantic Ocean from a point near Ocean City, Maryland. The photographs taken over open water proved to be of little value. The flight was terminated at 0943 EDT. Seven pictures were taken over open water during parachute descent.

In a recovery accident, the camera package was ruptured and some water damage to some frames of each film occurred. Despite this damage and the fact that the early photography was taken at lower than preferred solar angles, the quality of the photography was satisfactory.

The ground tracks for both flights 1 and 2 are shown in figure 2. A few selected photograph outlines are depicted for each flight. The mission information for flights 1 and 2 is included in tables II and III, respectively.

## HOLLOMAN AIR FORCE BASE MISSION

### Preflight Preparations

A third photographic mission was flown as a "hitchhike" on a balloon launched from Holloman Air Force Base, New Mexico, on September 25, 1969. The NASA Langley "camera package team" was alerted to the opportunity 2 weeks prior to the flight. Although it was not possible to set up a complete experiment with ground-truth activity,



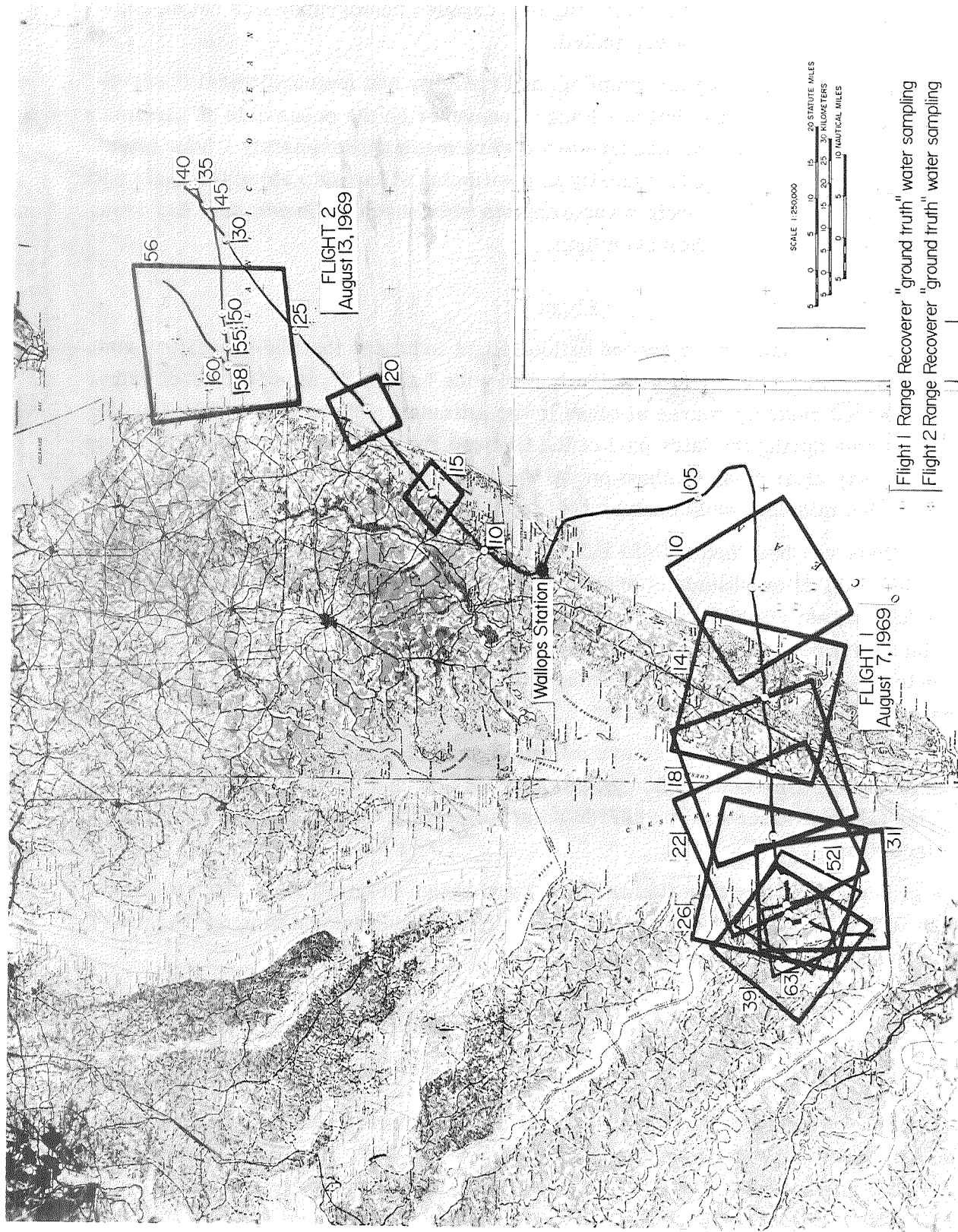


Figure 2.- Ground track and photographic outlines for flights 1 and 2 from Wallops Station, Virginia.  
(Numbers indicate frame.)



it was hoped that the track would cover ground common with the Apollo 9 SO65 experiment of March 1969. Film-filter combinations and exposure settings similar to those of the SO65 experiment were used and are shown in table I.

Because no command channel was available to operate the cameras on this flight, a timing circuit (intervalometer) was improvised that, based on an estimated balloon drift rate, would trigger the cameras at intervals that would yield some 50 to 60 percent overlap on successive photographs. The timing circuit would also require an initial delay to allow the balloon to reach high altitudes before taking pictures. The circuit is described in appendix A.

### Flight 3

The balloon was launched at 0545 MDT. Picture-taking began at about 0730 MDT with the balloon over a point about 28 km due south of Alamogordo, New Mexico, at an altitude of approximately 28 km. From that point, the balloon assumed an almost due-easterly course passing over Artesia and Hobbs, New Mexico, and into Texas. The photographic mission ended at about the New Mexico-Texas line. The major part of the imagery was taken from altitudes between 36 km and 38 km with each photograph covering more than 1700 km<sup>2</sup>. The flight 3 ground track is plotted on an area map. (See fig. 3.)

The camera package was parachuted to earth about 32 km south of Big Spring, Texas, on the morning of September 26, 1969. Camera 1 with the Ektachrome Infrared Aero Film, Type 8443, had failed after the first two pictures. The black and white photography from the remaining three cameras, however, exhibited excellent quality in both contrast and resolution.

### PHOTOGRAPH CODING

Each photograph from the three balloon flights is identified by a four-digit number. The first digit indicates the flight (1, 2, or 3); the second digit the camera position (1, 2, 3, or 4; see table I); and the third and fourth digits the frame number (01, 02, . . . 35, 36, etc.) As previously noted, there are no data for cameras 3 and 4 from flight 1 and camera 1 from flight 3.

### DISCUSSION OF RESULTS

The flight 1 mission provided approximately 1/600 000 scale photography of Virginia's Eastern Shore and lower Chesapeake Bay. This large-area imagery revealed interesting information on the coastlines and estuary that perhaps had not been significantly appreciated with larger scale aerial photography. For instance, photographs 1114 and 1115 (also 1214 and 1215) depict in single photographs the contrast between the lagoon

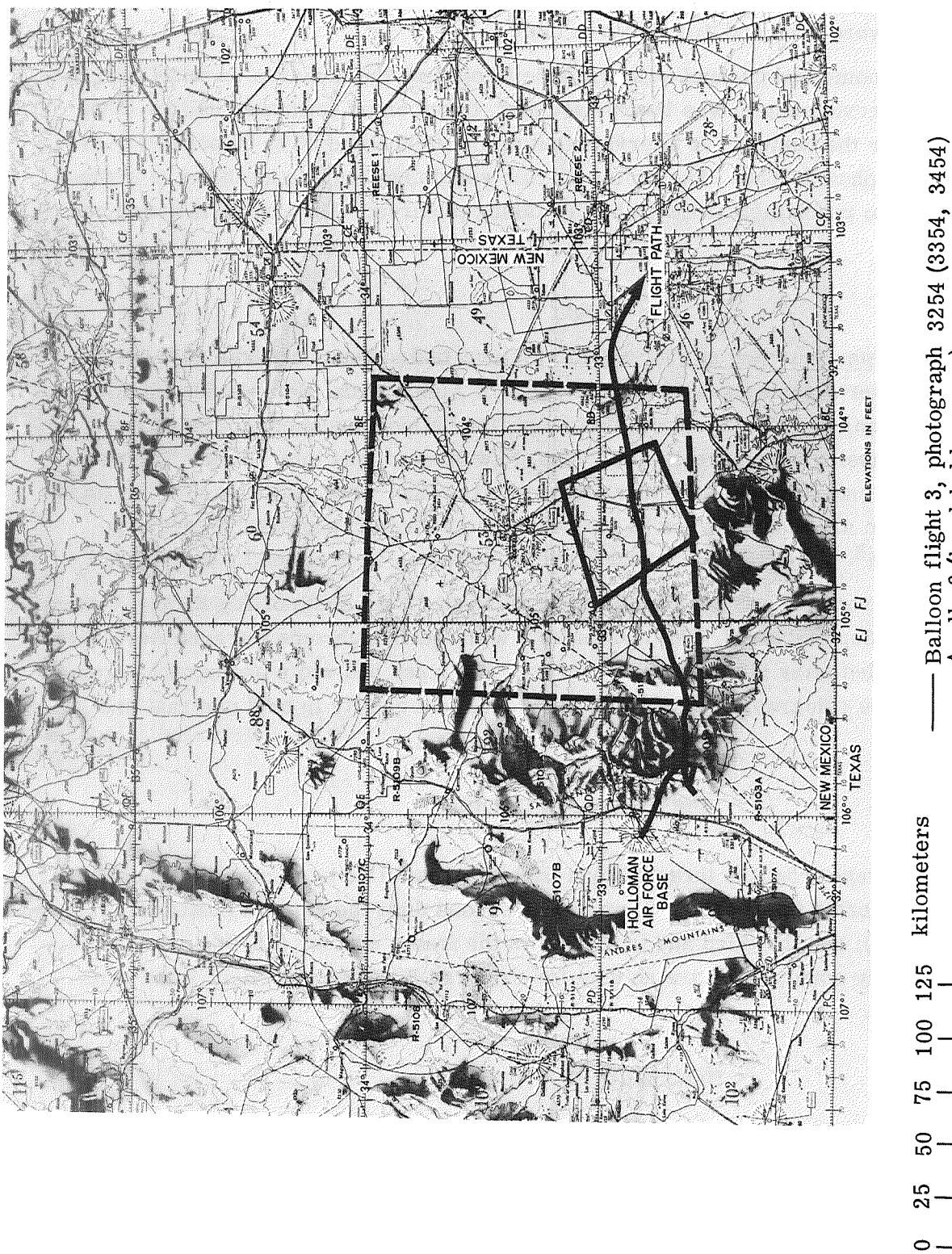


Figure 3.- Ground track from flight 3 (Holloman Air Force Base, New Mexico).

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waters on the ocean side of the Eastern Shore between the mainland and the barrier islands, and the waters of eastern Chesapeake Bay.

Photographs 1114 and 1214 were compared with aerial photography taken in 1959. (See fig. 4.) Changes in the barrier islands and inlets from sediment redistribution are obvious. Selected flight 1 and flight 2 photographs have been provided to the Department of the Army, Corps of Engineers to assist them in their evaluation of the coastline-erosion problems in this area and in the bay. State agencies have expressed an interest in the photography as land-use maps for planning purposes. To these state and municipal planners, periodic, small-scale photography has very direct and practical usefulness.

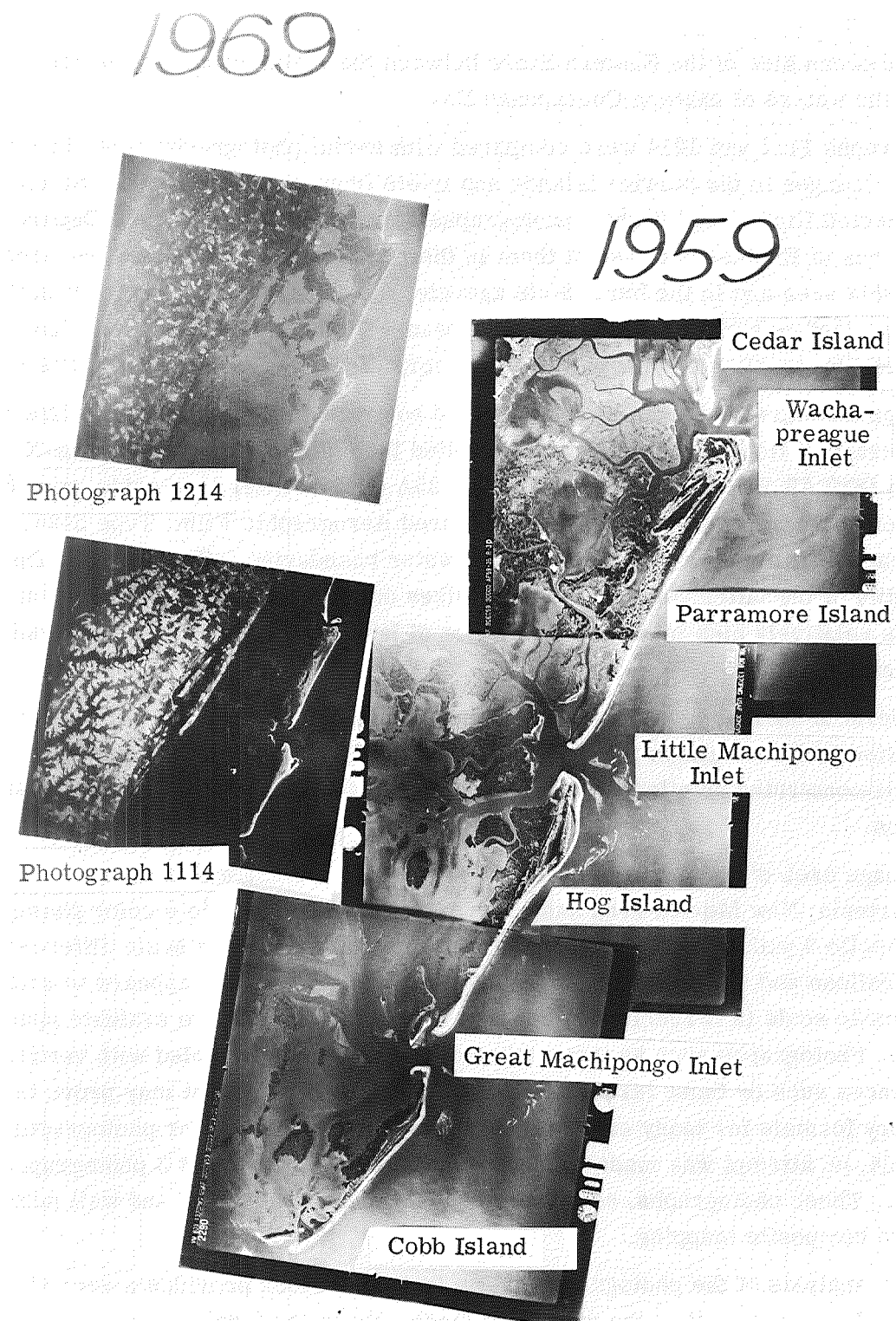
Although photographed at lower than desired solar angles, the black and white multi-spectral coverage of tidal areas in flight 2 exhibited the ability of the Kodak Plus-X Aerographic Film (ESTAR Base), Type 2401, with the 25A (Red 1) filter to provide good discrimination of land targets and of the Kodak Infrared Aerographic Film, Type 5424, with the 89B (Infrared) filter to clearly identify land-water boundaries. (See fig. 5.) The infrared quality of the latter combination capitalizes on the high infrared absorption of water and the relatively high infrared reflectance of land forms to produce high-contrast land-water imagery.

Considerable difficulty was encountered in coordinating the ground-truth shipboard experimentation with the balloon mission. Helicopters capable of landing on water, on the other hand, demonstrated an effective means of gathering coincident ground-truth data for such missions.

The image area of photographs 3254, 3354, and 3454 for flight 3 is shown in figure 3. It is of the Artesia, New Mexico area and covers land area common to a color photograph taken from Apollo 9 with a hand-held camera (photograph 3449). The scale difference between the balloon and spacecraft photographs is about 3 to 1, which appears to constitute a reasonable scale (and resolution) interval from which to begin to evaluate space photography. Photographs such as these taken over New Mexico coupled with vertically nested sequences such as those taken during flight 1 parachute descent may prove to be useful imagery formats for many earth survey applications. Except for photographs 3254, 3354, and 3454, no attempt was made to locate geographically the flight 3 photographs on an area map. These photographs, however, are generously overlapped and well suited for individual and composite mapping.

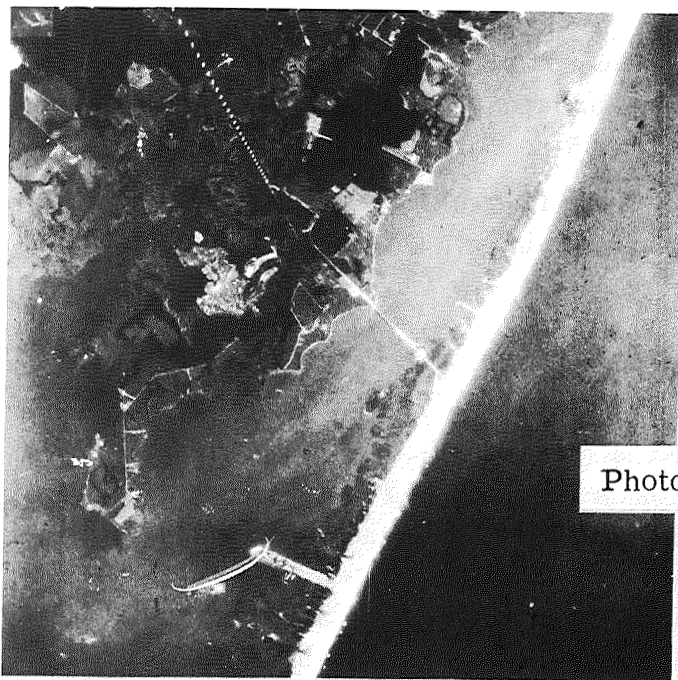
Further analysis of the photography shows that the balloon provides a very stable experimental platform except in the rotational mode, where the frequency is low and irregular. For earth-looking photographic applications, these rotational effects are negligible. Most of the pictures taken from the balloon were essentially nadir pointing.

The 2-week notice for the Holloman flight was adequate for the "strap-on" hitchhike application. ("Strap-on" indicates a minimum interface situation with either balloon or



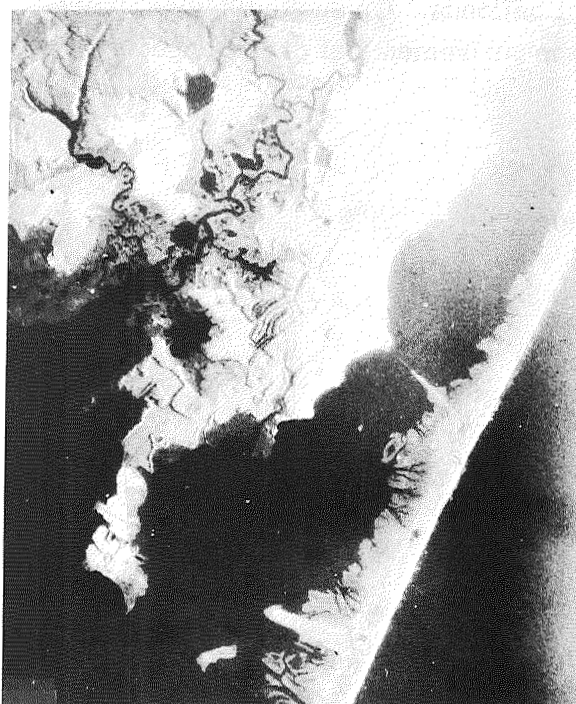
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Figure 4.- Comparison of 1969 balloon photography with 1959 aerial photography.



Photograph 2218

Film: Kodak Plus-X Aerographic  
Film (ESTAR Base),  
Type 2401  
Filter: 25A (Red 1)



Photograph 2418

Film: Kodak Infrared Aerographic  
Film, Type 5424  
Filter: 89B (Infrared)

Figure 5.- Black and white multispectral photography from flight 2.

L-71-558

primary experiment operations. Power or command requirements presumably would have negated the flight opportunity.) The timing circuit signaled pictures at estimated  $4\frac{1}{2}$ - to 5-minute intervals following an estimated 5-hour initial delay.

The time interval was less than the 7-minute interval measured in preflight tests due to temperature effects on the electrical components of the timer. (See appendix A for discussion.)

### CONCLUDING REMARKS

The three photographic missions flown on high-altitude, free-flight balloons demonstrated the excellent stability of these platforms for conducting vertical, earth-looking, imaging experiments. The photography obtained from these missions further demonstrated the potential usefulness of these balloons as intermediate-altitude (9 to 38 km), air-truth platforms for correlating satellite imagery with lower altitude aircraft imagery. Specifically, the near-vertical parachute descent of the operating cameras from balloon altitudes down to approximately 9 km illustrated a simple technique for acquiring nested photographic sequences so uniquely useful for such correlations.

On the other hand, the missions also revealed the difficulty in coordinating ground-truth experimentation with imaging from free-flight balloons. On such missions, therefore, it appears inadvisable to plan for correlative measurements at prearranged ground sites.

Langley Research Center,  
National Aeronautics and Space Administration,  
Hampton, Va., April 28, 1971.



## APPENDIX A

### PHOTOGRAPHIC SYSTEM CHARACTERISTICS

#### Camera Characteristics

The camera chosen for the photographic experiment consists of the Hasselblad 500EL camera body with a 70-mm magazine and a 50-mm focal-length, f/4 Zeiss Distagon lens, which possessed the following operational characteristics:

- (1) A self-contained frame-advance system which operates automatically after each exposure command
- (2) Image format of 57.2 mm by 57.2 mm and the magazine with a 70-exposure capability
- (3) Film in an easily detachable magazine
- (4) Weight of 2.82 kg
- (5) Procured as off-the-shelf equipment
- (6) Lens field of view of  $75^{\circ}$  (diagonal)

The description and weight breakdown of the camera appear in tables IV and V, respectively. Nine complete cameras and an extra magazine were purchased. Eight cameras were designated for flight with a spare camera and magazine as backup.

#### Film Selection and Characteristics

The photographic film selected for these flights was based upon recommendations of the experimenters. Film characteristics appear in table VI. Data for this table were compiled from references 1 and 2. A sensitometric strip was preexposed on the leader of each roll of color-infrared film to act as a control. The film-characteristic curves are shown in figure 6. Consultation with Robert W. Pease, University of California, revealed that color correction filters, which occasionally are used on cameras to balance the sensitivity in each layer of the emulsion (ref. 3), would not be necessary for this particular film batch and processing procedure.

#### Filter Selection and Spectral Transmission

The color filters selected for these flights were based upon recommendations of the experimenters and on recommendations of Manned Spacecraft Center (MSC) and Eastman Kodak personnel. These filters are listed in table I with their respective films and filter factors. The spectral transmission of each glass filter was measured on a Cary Recording

## APPENDIX A – Continued

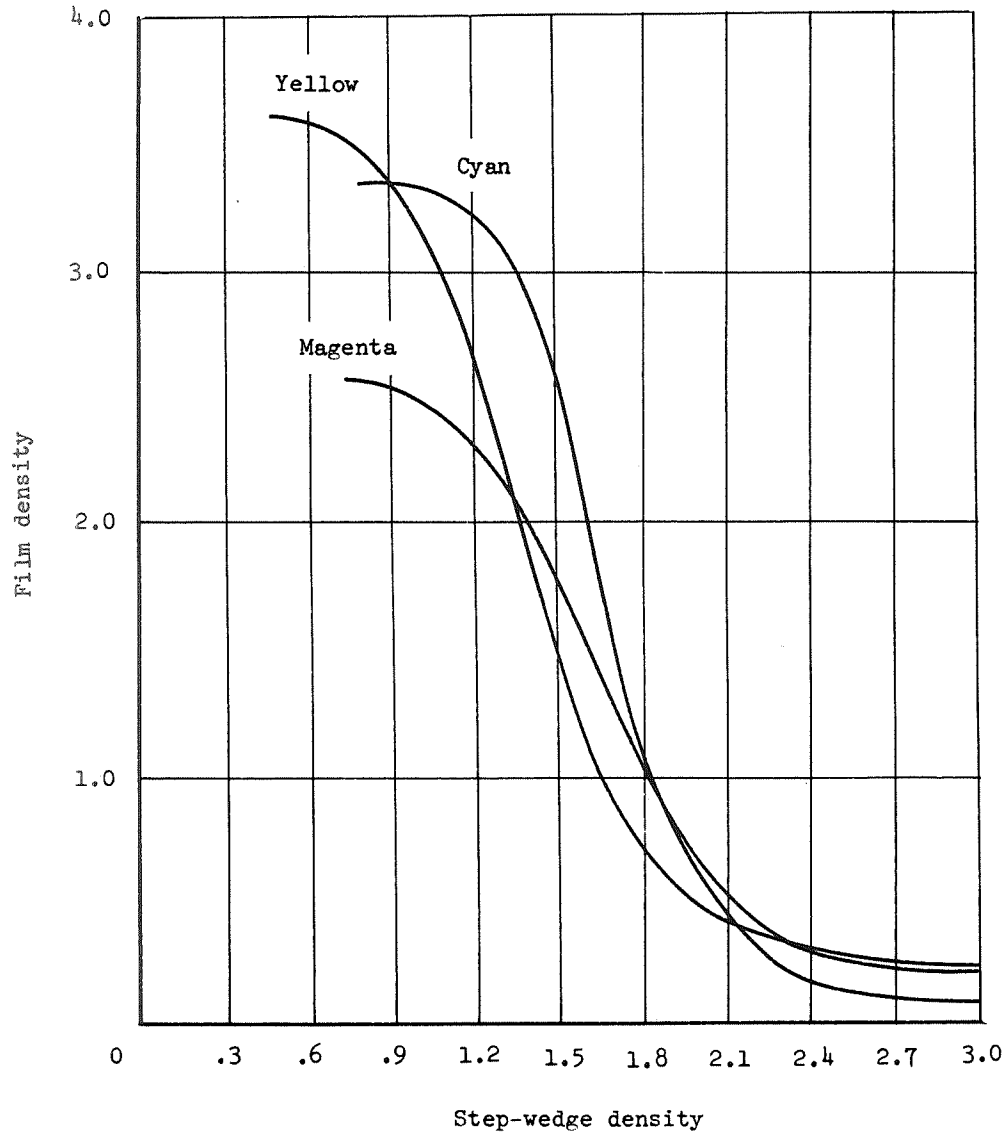


Figure 6.- Sensitometric data for color infrared film.

Spectrophotometer, Model 14, over the wavelength range  $0.4 \mu\text{m}$  to  $1.0 \mu\text{m}$ . The results of these measurements appear in figure 7.

### Window Selection and Spectral Transmission

The windows of the camera package were made of high-grade crown glass, 12.7 mm thick and 124 mm in diameter. Spectral transmission of the window material was measured to be a constant of 0.90 over the spectral range  $0.4 \mu\text{m}$  to  $1.2 \mu\text{m}$ . The transmission loss was due almost entirely to surface reflection. All windows were measured for parallelism and surface flatness by the manufacturer. All windows were found to have a wedge

## APPENDIX A - Continued

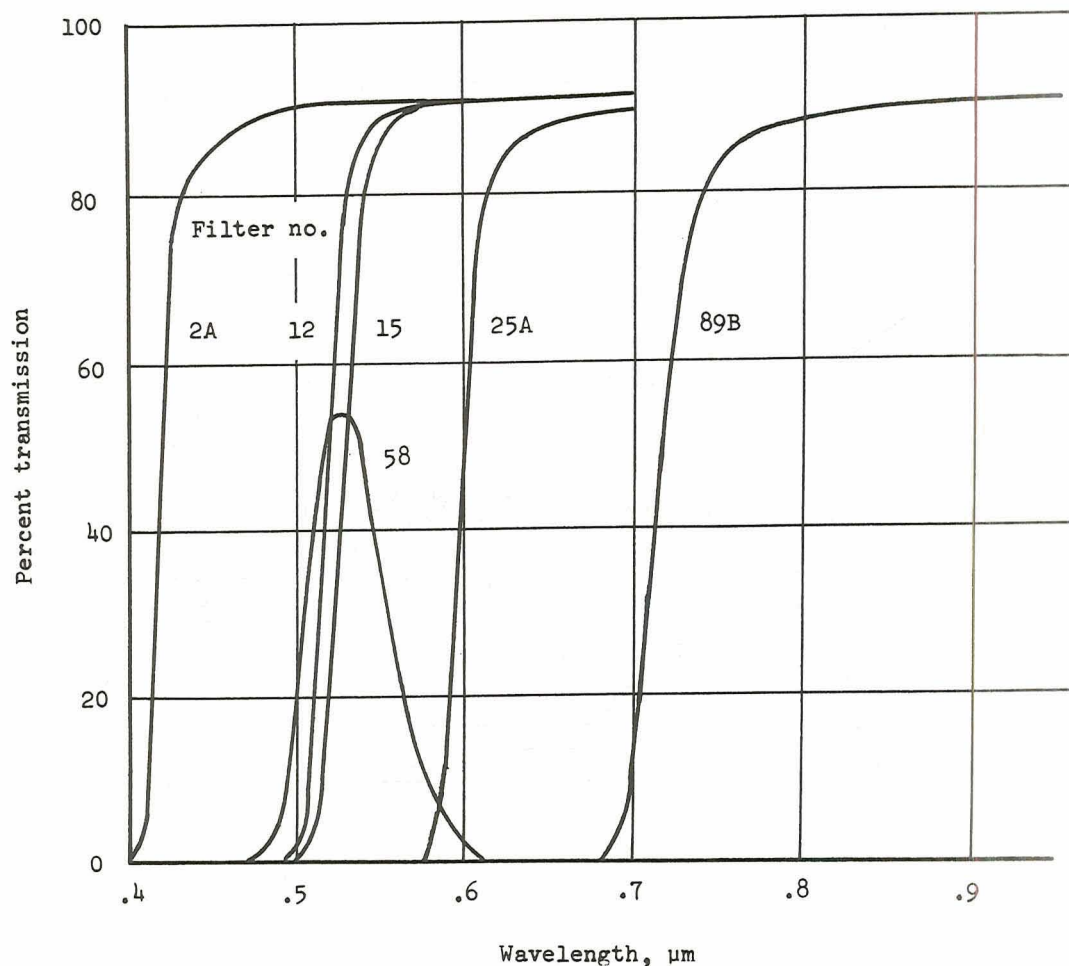


Figure 7.- Filter transmission.

of less than 1 minute of arc and surface flatness of no more than five fringes of mercury green light  $0.5461 \mu\text{m}$  and astigmatic to less than 2.5 fringes across the faces.

### Nodal-Point Measurement

Front nodal-point measurements were made on the camera lenses to determine how far from the camera-package window the lens could be placed and suffer no vignetting from the window mount or sunshade. The front nodal point is the axial intercept of two rays defining the camera field of view. Front nodal point for the lens was 38.7 mm behind the lens, shown in figure 8. A maximum distance of 19 mm between optical window and lens is also indicated in the figure.

### Boresighting Procedure and Accuracy

The cameras were boresighted by using a circular bubble level. After leveling the camera package, each camera was leveled by placing the bubble level on a flat plate

# APPENDIX A - Continued

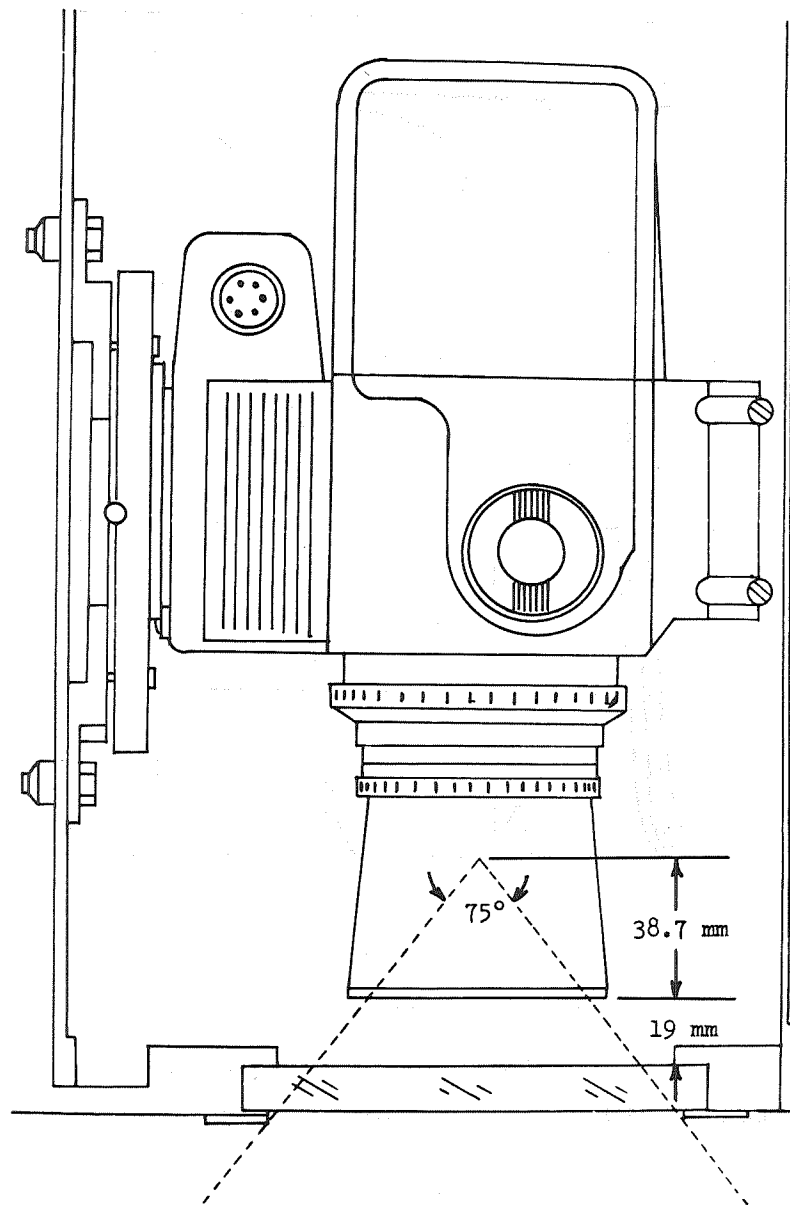


Figure 8.- Front lens nodal-point position.

resting in the focal plane, and adjusting pitch and yaw adjustments. This procedure insured that the cameras would maintain their boresight after package sealing by checking the levelness of the package on the balloon platform during preflight checkout. The overall leveling accuracy of this procedure was  $\pm 0.48^\circ$  ( $\pm 0.24^\circ$  each for package and cameras) or  $\pm 0.64$  percent of diagonal field of view. Maximum ground displacement error due to boresighting was then  $\pm 256$  meters from an altitude of 30.5 km, or  $\pm 0.42$  mm in the image plane.

## APPENDIX A – Continued

### Final-Exposure Determination

With the exception of the GAF films, whose exposure settings were determined by the investigator, the exposures for the color infrared, color, and black and white films were based on inputs from three sources: recommendation of MSC, Earth Observation Division personnel, and references 4 and 5. Although photography was scheduled over a wide range of solar-elevation angles (because of the anticipated time aloft), the aperture settings chosen for flight 1 would be adequate between 0800 EDT and 1600 EDT. Because the mission duration of flight 1 was much shorter than planned, the emphasis in flight 2 was on early morning sun elevations and consequently greater exposures. Also since most of the photography was scheduled over ocean water, which has less surface reflectance than continental surfaces, lens apertures were increased by 1.0 stop to allow for greater depth penetration. Lens exposure settings used are shown in table I.

### System Operational Tests

The constraint of a single command channel required the parallel connection of the leads from the four cameras in each package to an electrical plug connected to the command receiver. Because the cameras do not possess identical rewind cycle intervals, feedback from the cameras still operating could and did, during tests, trigger into operation those which had completed the operation. This feedback caused a runaway cycling which did not terminate until all cameras were individually and manually disconnected. To prevent this runaway situation in flight, diodes were inserted in one lead of the pair of leads from each camera to the command receiver plug. The schematic of the electrical hookup is shown in figure 9. After these corrective measures were taken, tests were conducted satisfactorily through a simulated telemetry link.

### Flight 3 Intervalometer

The intervalometer, or timing circuit, for the Holloman mission (flight 3) was designed, breadboarded, and tested for repeatability just prior to flight. The timer consisted essentially of two resistance-capacitance (RC) circuits (fig. 10) in which the first circuit (time constant approximately equal to 5 hours) actuates a latching relay for the second (time constant approximately equal to 7 minutes). This system was wired into the center well of the camera package and connections made to the camera command plug on the upper plate of the camera housing.

Three interchangeable electrical plugs were provided for the field operations:

- (1) Camera plug 1 allowed testing of the 5-hour time constant.
- (2) Camera plug 2 allowed bypassing of the 5-hour time constant to check the 7-minute time constant.

## APPENDIX A - Continued

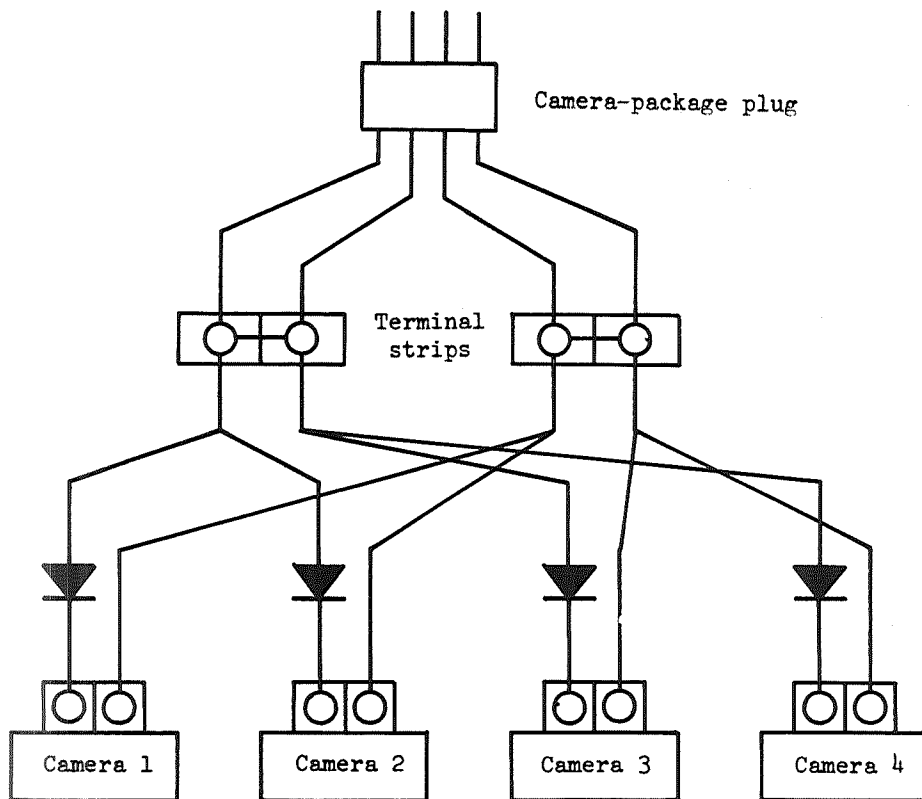


Figure 9.- Camera circuit.

(3) Camera plug 3, designated "flight plug," allowed the sequence of one 5-hour interval and thereafter one command pulse every 7 minutes.

Immediately before flight, camera plug 1 was inserted momentarily to reset the latching relay and discharge any residual charge on the capacitor; it was then removed and camera plug 3 inserted for flight. The option was provided that if the launch were delayed (or canceled), plug 3 could have been removed; thus, the camera timer would be disconnected. Later, the same sequence of plugs 1 and 3 could again have been used when flight became imminent.

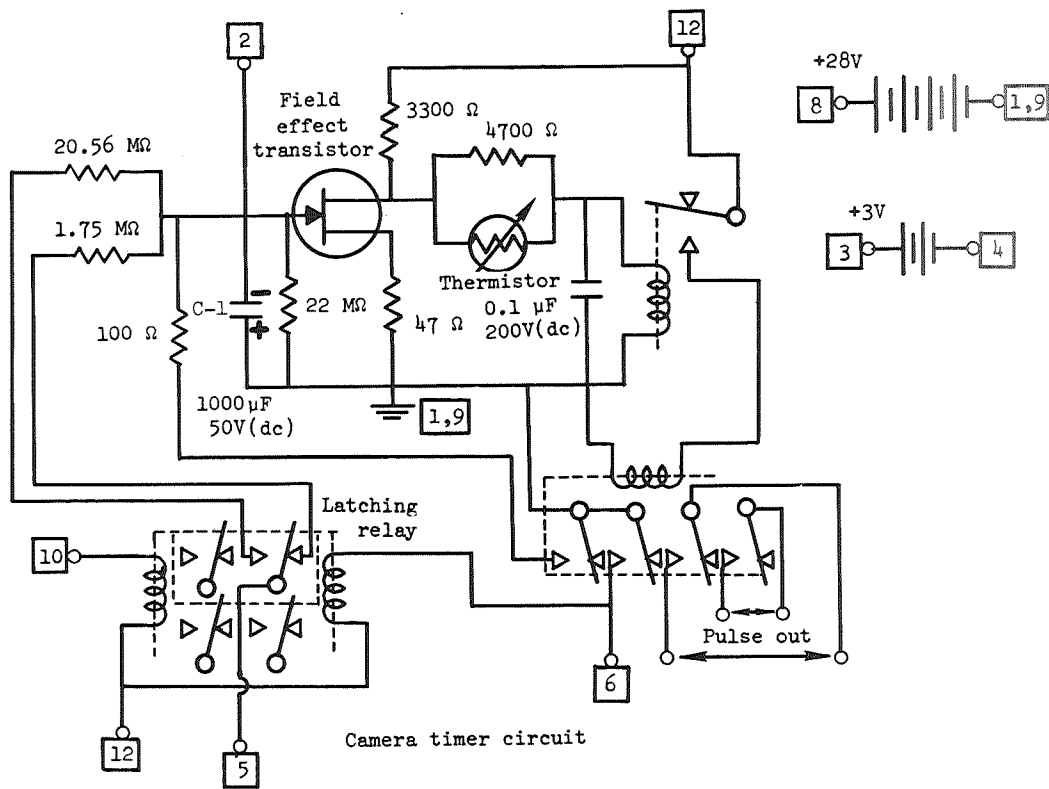
Actual time intervals for the short time constant turned out to be closer to 5 minutes because of temperature effects on the capacitor, C-1 (see fig. 10). The lowered temperature experienced in flight permitted higher residual charge on C-1 and consequently shorter times between pictures.

### Film Recovery, Processing, and Duplication

The flight 1 film was refrigerated immediately after recovery and processed within 48 hours. Because of the recovery accident in flight 2, the film had been exposed to salt



# APPENDIX A - Continued



Camera-package plug  
(female)

Interchangeable plugs  
(male)

		Plug 1	Plug 2	Plug 3 "Flight plug"
1	Ground	1	1	1
2	Cap. discharge	2	2	2
3	+3V(battery)	3	3	3
4	-3V(battery)	4	4	4
5	-3V(timer)	5	5	5
6	Short time(7 min.)	6	6	6
7		7	7	7
8	+28V(battery)	8	8	8
9	Ground	9	9	9
10	Long time(5 hr.)	10	10	10
11		11	11	11
12	+28V(timer)	12	12	12

Pin-connection diagram

Figure 10.- Intervalometer.

## APPENDIX A - Concluded

water and room temperature for at least 30 hours before refrigeration. Processing of flight 2 film took place within 24 hours after refrigeration. The flight 2 film suffered some water damage which affected the last 16 frames of each film roll; the remaining 47 frames were undamaged.

The black and white film was processed in a Kodak Versamat film processor, model 11C to a film contrast (gamma) of 0.8 using Hunt's Type B Starmat processing chemistry. The color and color infrared film (Eastman Kodak) were processed to reversal transparency in a Kodak Ektachrome RT Processor, Model 1411-M, with EA-4 chemistry. The GAF 1000 Blue-Insensitive Color Film, Type 2575, and the GAF Ansochrome D/500 Gafstar Color Aerial Film, Type 7550, were processed to reversal transparency by the AR-2 process for GAF film. The black and white film was duplicated on Kodak Fine Grain Aerial Duplicating Film, Type 2430, and processed in a Kodak Versamat Process, Type 641. The color and color infrared film were duplicated on Kodak Aerial Color Film (ESTAR Thin Base), Type SO-121 and processed in a Kodak Ektachrome RT Processor, Model 1411-M, with EA-4 chemistry. The color duplication was performed at Data Corporation, Dayton, Ohio.

## APPENDIX B

### CAMERA-PACKAGE DESIGN

#### Design Constraints

A camera package was designed which would maintain a differential pressure of 1 atmosphere and survive loads induced from a water entry at 7.62 to 9.15 m/sec without damage. Flight and recovery requirements dictated a weight-limited structure with a positive margin of buoyancy.

#### Basic Configuration

The camera package consists of two major components: a cylindrical outer shell and an inner core which is machined to accept the four Hasselblad cameras. (See fig. 11.) The cylindrical shell has a maximum diameter of 51.4 cm, an overall length of 34.2 cm, and a wall thickness of 0.229 cm. The core is a welded structure consisting of a 10.5-cm  $\times$  11.3-cm well-center section, four webs, 90° apart, and two end support plates. The aft support plate has a maximum diameter of 49.9 cm with a 0.076-cm rim thickness. An O-ring groove is machined into this rim for sealing purposes, and three raised bosses, 120° apart are provided on the exterior surface and used to accept the camera-package suspension system. The forward support plate has a maximum diameter of 51.4 cm and is 1.91 cm thick. An O-ring groove is also machined into the rim of this plate. In addition, 16 threaded holes are tapped into this rim and are used to secure the cylindrical shell to the core. Four holes, 10.7 cm in diameter, are machined into this plate, 90° apart, on a 34.0-cm-diameter circle. These openings accept O-ring sealed windows which provide the view ports for the cameras. External sunshades are fitted about each window port to eliminate reflections into the field of view. A weight breakdown of the camera-package structures appears in figure 12.

#### Camera Alinement and Support

A set of four adjustment plates are used to allow each camera a limited amount of adjustment:  $\pm 2^\circ$  pitch and  $\pm 9^\circ$  yaw. (See fig. 13.) These plates are adjusted through the use of retaining screws placed symmetrical to the axes of rotation and, thus, working in opposition, afford a self-locking feature. Once alined, the cameras are maintained in position against the adjustment plates with bungee cords, two of which span each camera and lock into a web on either side of the camera. (See fig. 14.) These cords are also designed to reduce the shock load on each camera at the time of impact.

# APPENDIX B - Continued

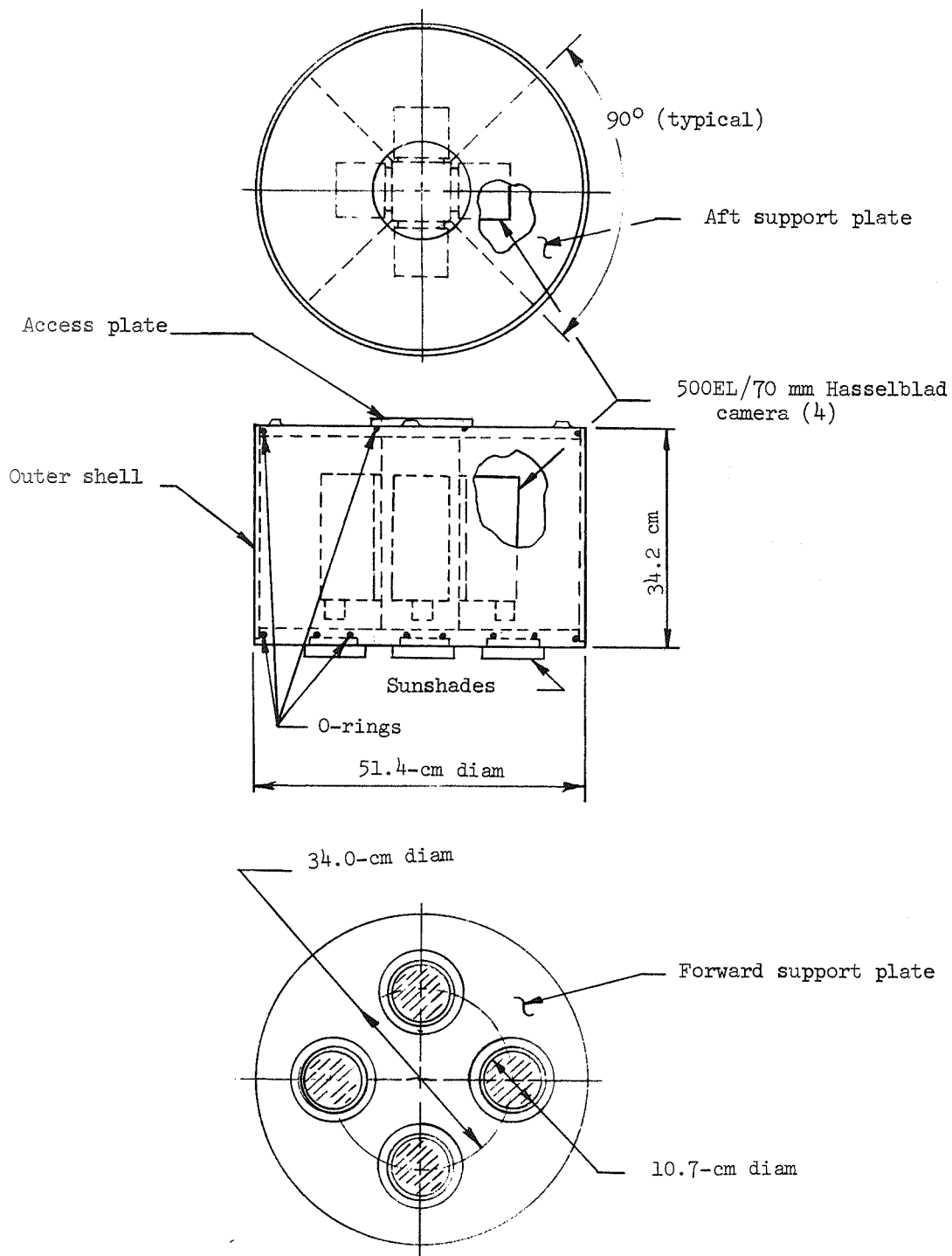
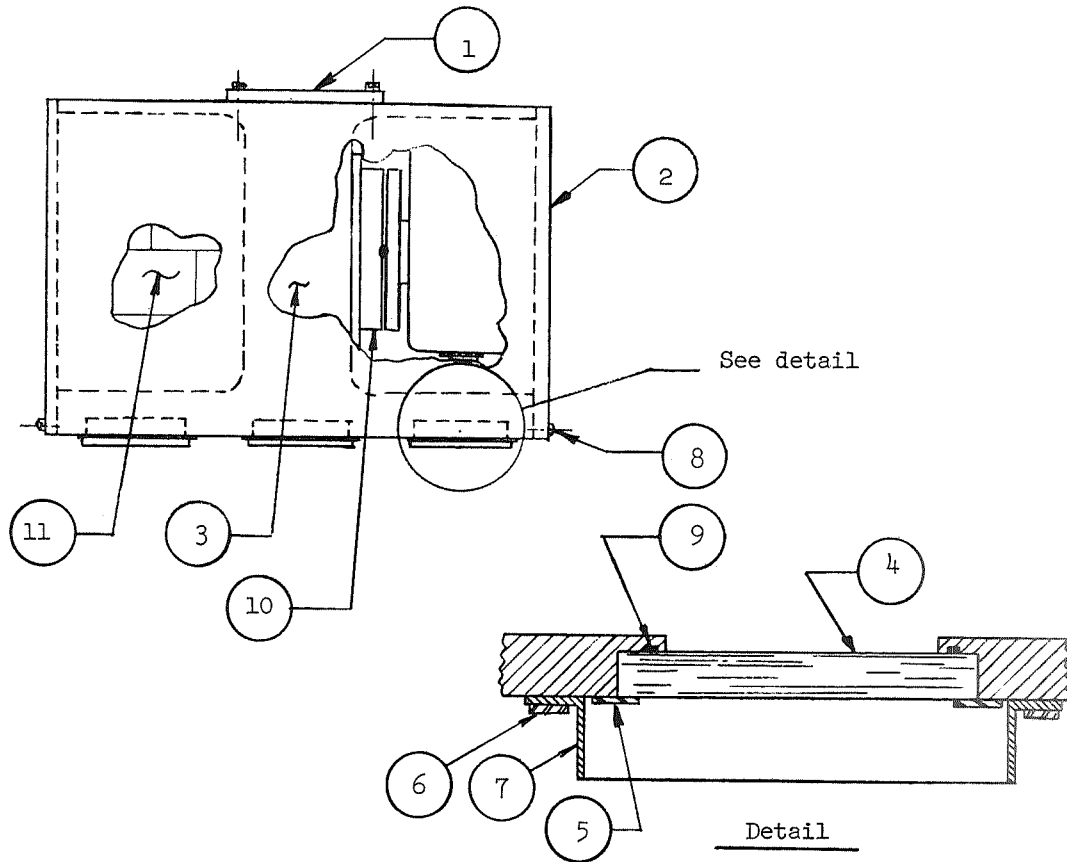


Figure 11.- Camera-pack configuration.

# APPENDIX B - Continued



Part	Description	Material	Weight, kg	Minimum margin of safety
1	Access plate	2024-T3 aluminum alloy	0.499	+0.62
2	Outer shell	6061-T6 aluminum alloy	3.810	+1.81
3	Inner core	6061-T6 aluminum alloy	10.800	+ .58
4	Window (4)	Crown glass	1.630	+2.00
5	Window retainer (4)	2024-T3 aluminum alloy	.181	-----
6	Sunshade retainer (4)	2024-T3 aluminum alloy	.091	-----
7	Sunshade (4)	2024-O aluminum alloy	.091	-----
8	Screws, washers, nuts	Steel	.295	-----
9	O-rings	Neoprene rubber	.091	-----
10	Camera adjustment plates	2024-T4 aluminum alloy	2.040	-----
11	Foam	Closed-cell urethane	2.490	-----

Figure 12.- Camera-package structural information.

APPENDIX B - Continued

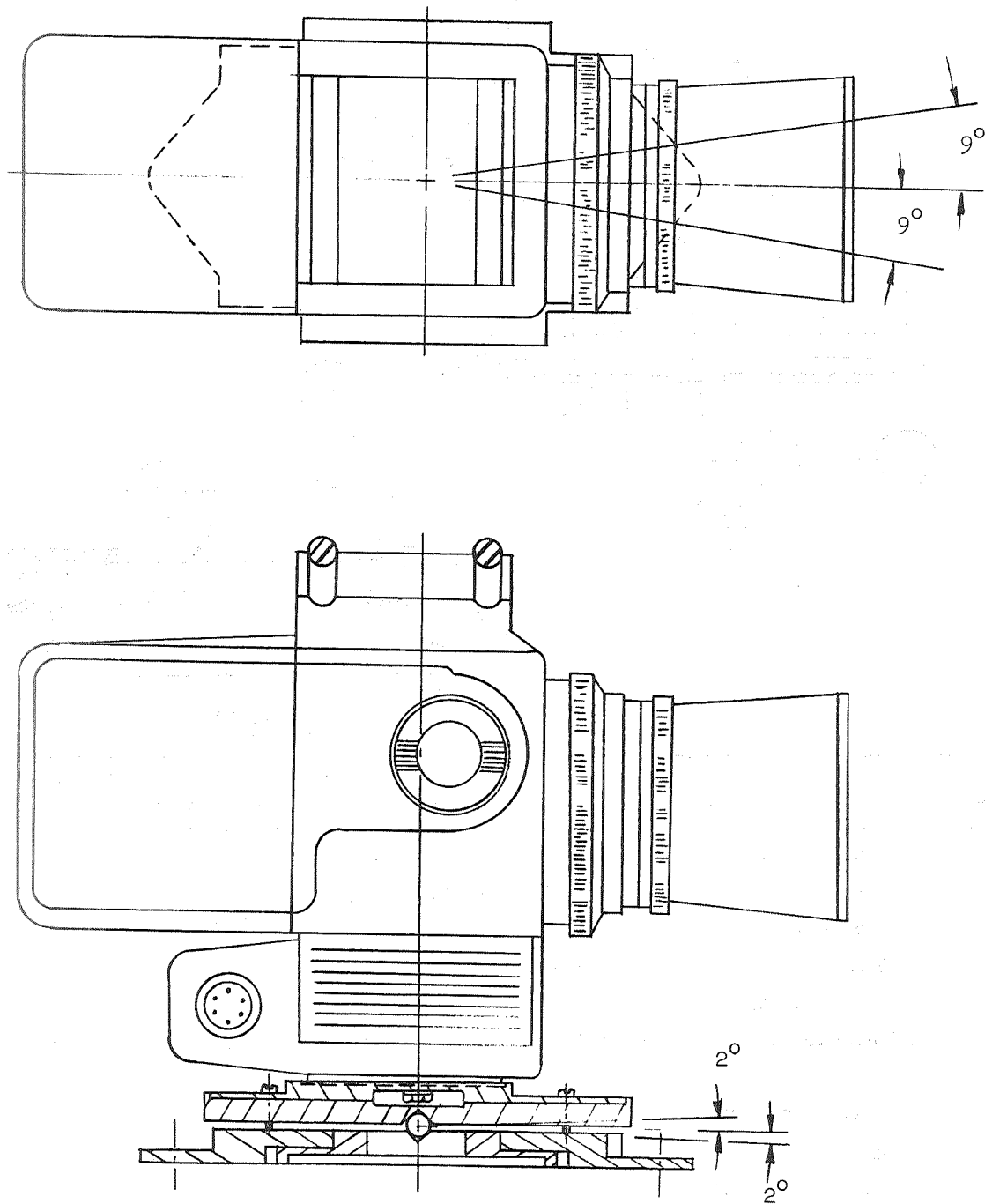
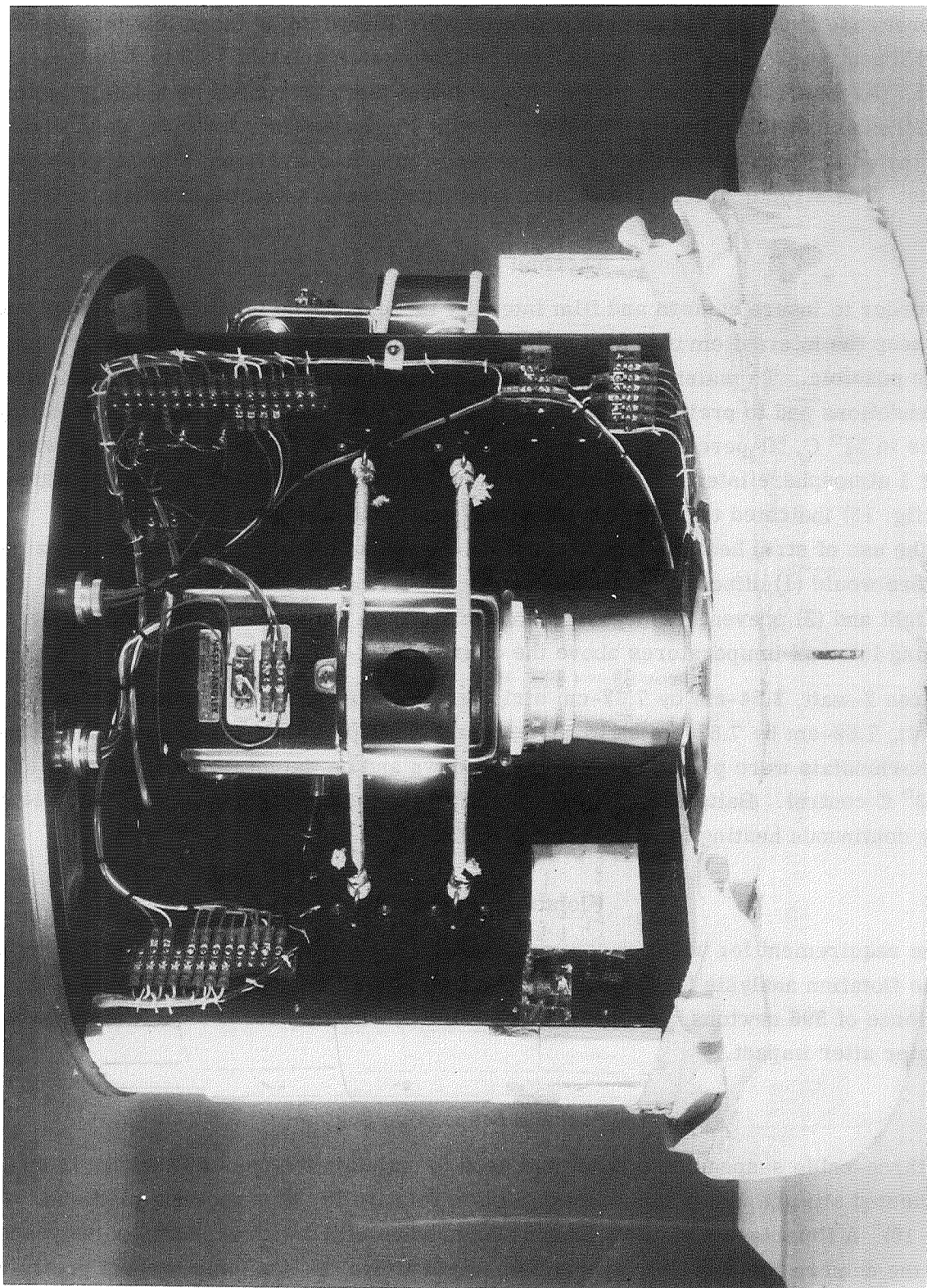


Figure 13.- Camera mounting-plate adjustment.





L-70-3017

Figure 14.- Camera installation.

## APPENDIX B – Continued

### Loads Analysis

Worst case loads for the camera packages were identified as those that might result from a differential pressure of 1 atmosphere or from water entry of 7.62 to 9.15 m/sec at impact. To meet these requirements, design levels were increased by a safety factor of 1.5. Schedule considerations precluded preflight impact testing; however, each flight unit was tested to flight-acceptance levels corresponding to operational thermal-vacuum conditions. The structural features of the camera package are identified in figure 12.

### Thermal Analysis

In order to insure camera and film integrity throughout the mission, an attempt was made to keep the internal environment of the camera package as close to laboratory conditions as possible. To maintain a film temperature compatible with the manufacturer's recommendations and to prevent fogging, all camera-package assembly and film handling took place in 21° C, 50-percent relative humidity conditions. The camera package was sealed at 1 atmosphere internal pressure by using ambient air. Thermal-balance studies (see fig. 15) indicated the need for additional heat input which was accomplished through the use of strip heaters around the windows and on the back of the film magazines. The heaters would (1) offset the low temperature experienced by the camera package during flight and (2) prevent the deposition of moisture on the inside of the windows by maintaining internal temperatures above the dewpoint.

Three 2-watt, 2.54-cm by 7.62-cm strip heaters were placed around each window. One 5-watt, 7.62-cm by 7.62-cm strip heater was installed on the back of each film magazine. Thermostats were placed close to the windows and on the magazines, allowing an  $18^{\circ}\text{C} \pm 3^{\circ}\text{C}$  control. Batteries mounted external to the camera package were sufficient to supply continuous heating for a 10-hour mission.

### Flotation Analysis

The requirement for water recovery dictated a buoyant design for the camera package. The flotation analysis for the 32.7-kg package (weight = 320 newtons) indicated a buoyant force of 396 newtons, thus providing sufficient buoyancy for the camera package in the water after impact.

### Camera-Package Suspension System

A three-cable suspension system was used to maintain the camera package in an earth-oriented attitude with a minimum of motion relative to the supporting platform. (See fig. 16) A flexible system was chosen which, when allied with expanded polystyrene between the camera package and support bar, would afford the maximum impact protection at landing. From the standpoint of photography, the three-cable suspension was adjudged

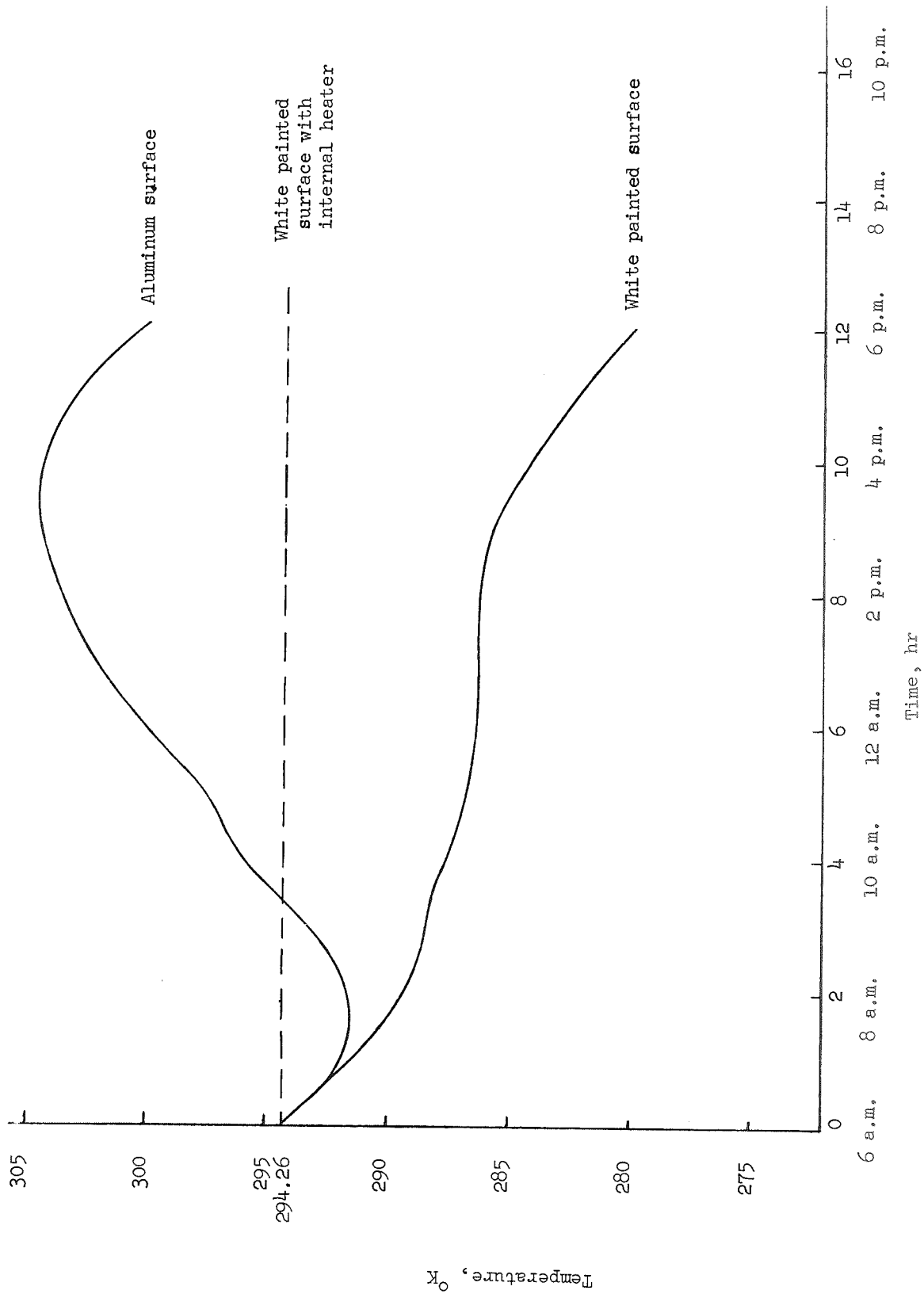


Figure 15.- Estimated temperature-time profiles for camera package interior.

APPENDIX B - Continued

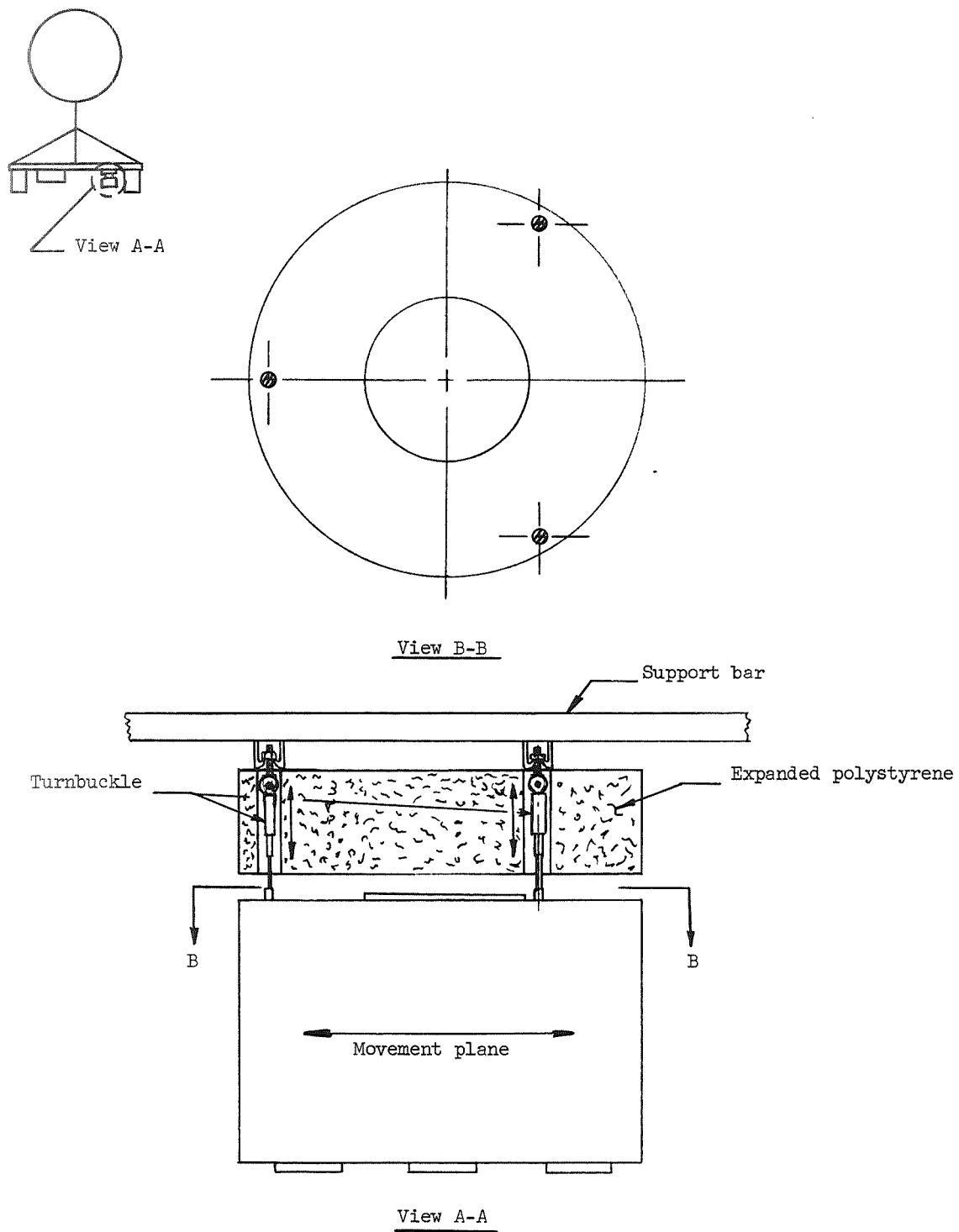


Figure 16.- Camera-package suspension system.

## APPENDIX B – Concluded

superior to the single-point suspension (at the support bar) since it prevented pendulous oscillation and restricted camera motion to horizontal translation. The suspension system consisted of 0.318-cm stainless-steel cables and turnbuckle assemblies. Adjustment of the turnbuckles allowed leveling of the camera package. The low rotational frequency of the complete system (balloon and platform) was inconsequential.

### Field Operations

The camera packages for flight 1 and flight 2 were completely rechecked upon arrival at the launch site. The film magazines were attached to the cameras, and after final assembly in a controlled environment, each camera package was subjected to pressure checks to insure a sealed system.

For flight 3, which required a quick response time, the camera package (complete with loaded film magazines) was shipped and stored under normal handling conditions. This operation provided a nearly service-free package at the launch site and allowed maximum emphasis to be placed on the interface between the camera package and the launch vehicle.

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TABLE I.- FILM-FILTER COMBINATIONS AND EXPOSURE SETTINGS

Flight	Camera	Film	Filter number	Filter factor	Film exposure time, sec	Aperture ratio	Focus, meters
1 (Wallops)	1	Kodak Ektachrome Infrared Aero Film, Type 8443	12 (Yellow)	(a)	$\frac{1}{125}$	f/11	$\infty$
	2	Kodak Ektachrome MS Aerographic Film (ESTAR Base), Type 2448	2A (Haze)	----	$\frac{1}{125}$	f/8	$\infty$
	3	GAF 1000 Blue-Insensitive Color Film, Type 2575 (Formerly 48892)	-----	----	$\frac{1}{125}$	f/16	$\infty$
	4	GAF Anscochrome D/500 Gafstar Color Aerial Film, Type 7550	12 (Yellow)	2.0	$\frac{1}{125}$	f/8	$\infty$
2 (Wallops)	1	Kodak Ektachrome Infrared Aero Film, Type 8443	12 (Yellow)	(a)	$\frac{1}{125}$	f/8	$\infty$
	2	Kodak Plus-X Aerographic Film (ESTAR Base), Type 2401	25A (Red 1)	4.0	$\frac{1}{125}$	f/11	$\infty$
	3	Kodak Plus-X Aerographic Film (ESTAR Base), Type 2401	58 (Dark green)	8.0	$\frac{1}{125}$	f/8	$\infty$
	4	Kodak Infrared Aerographic Film, Type 5424	89B (Infrared)	3.0	$\frac{1}{125}$	f/22	$\infty$
3 (Holloman)	1	Kodak Ektachrome Infrared Aero Film, Type 8443	15 (Deep yellow)	(a,b)	$\frac{1}{250}$	f/8	$\infty$
	2	Kodak Plus-X Aerographic Film (ESTAR Base), Type 2401	25A (Red 1)	4.0	$\frac{1}{250}$	f/8	$\infty$
	3	Kodak Plus-X Aerographic Film (ESTAR Base), Type 2401	58 (Dark green)	8.0	$\frac{1}{250}$	f/5.6	$\infty$
	4	Kodak Infrared Aerographic Film, Type 5424	89B (Infrared)	3.0	$\frac{1}{250}$	f/16	10

<sup>a</sup>In aerial exposure index.

<sup>b</sup>The difference in transmission between the 12 (Yellow) and the 15 (Deep yellow) filters is not enough to affect exposure settings for Kodak Ektachrome Infrared Aero Film, Type 8443.

TABLE II.- FLIGHT 1 MISSION INFORMATION<sup>a</sup>

[Date of flight, August 7, 1969; launch site, NASA Wallops Station;  
sky condition, zero-percent cloudiness but heavy haze]

Frame number	Eastern daylight time	Balloon position			Sun elevation, deg
		Ground range from Wallops, km	Azimuth from Wallops	Altitude, km	
5	0710	32.0	140°30'	12.6	17
10	0836	36.4	179°10'	29.0	31
14	0856	46.0	211°30'	31.0	33
18	0909	57.4	224°50'	30.7	35
22	0920	69.1	233°10'	30.0	37
26	0928	78.6	236°	29.4	39
31	0934	83.7	238°10'	23.5	40
39	0936	85.3	238°30'	21.1	40
43	0937	86.0	238°40'	20.2	40
52	0940	87.4	239°	17.8	41
58	0946	87.6	238°15'	13.9	42
63	0951	88.7	236°50'	11.6	43
68	0956	94.5	234°40'	9.63	44

<sup>a</sup>Selected photographs.

TABLE III.- FLIGHT 2 MISSION INFORMATION<sup>a</sup>

[Date of flight, August 13, 1969; launch site, NASA Wallops Station;  
sky condition, clear at low altitudes along coast and high  
scattered cirrus clouds offshore]

Frame number	Eastern daylight time	Balloon position			Sun elevation, deg
		Ground range from Wallops, km	Azimuth from Wallops	Altitude, km	
10	0710	25.2	13°36'	7.05	11
15	0725	40.6	21°54'	8.69	14
20	0740	63.4	34°12'	11.0	17
56	0943	96.3	32°	29.3	40

<sup>a</sup>Selected photographs.

TABLE IV.- CAMERA CHARACTERISTICS

Characteristic	Description
Camera body . . . . .	Hasselblad 500EL
Lens . . . . .	Zeiss Distagon; 50-mm focal length; 75° diagonal field of view; Synchro-Compur Shutter; exposure time, 1 to 1/500 sec; f/4 to f/22; 50 cm to $\infty$ focusing range
Magazine . . . . .	For 70-mm film; holds 4.9 meters of 0.13 mm (5.2 mil) base film (70 exposures)
Film . . . . .	Specification no. 488
Power . . . . .	Two 6.25-V nickel-cadmium batteries (5-series button cells); 1000 exposures on single charging
Exposure rate . . . .	Single shot and free running (1 frame/sec); manually set

TABLE V.- CAMERA WEIGHT BREAKDOWN

Camera part	Weight, kg
Camera body . . . . .	0.91
Lens . . . . .	0.93
Magazine . . . . .	0.51
Batteries (2) . . . . .	0.28
Empty cassette . . . . .	0.06
Loaded cassette . . . . .	0.13
Camera viewer . . . . .	0.09 (not used in flight)
Total weight per camera . . . . .	2.91

TABLE VI.- FILM CHARACTERISTICS

Manufacturer	Film	Type	Base	Base thickness		Aerial exposure index	Resolution, lines/mm, for a target object contrast of -		Root-mean-square granularity	Process type	Sensitivity
				mm	mils		1000:1	1.6:1			
Eastman Kodak Company (ref. 1)	Plus-X Aerographic	2401	ESTAR	0.10	4	80	100	51	$32 \times 10^{-3}$	Hunt's Type B Starmat <sup>b</sup>	Black and white (panchromatic)
	Infrared Aerographic	5424	Acetate Butyrate	0.13	5.2	125	89	28	39	Hunt's Type B Starmat <sup>b</sup>	Black and white (infrared)
	Ektachrome Infrared Aero	8443	Triacetate	0.13	5.2	10	71	36	22	EA-4	Color (infrared)
	Ektachrome MS Aerographic	2448	ESTAR	0.10	4	6	80	36	12	EA-4	Color (medium speed)
	Fine Grain Aerial Duplicating	2430	ESTAR	0.10	4	(a)	285	120	8.9	641	Blue
	Aerial Color	SO-121	ESTAR	0.06	2.5	6	160	80	15	EA-4	Color
GAF Corporation (ref. 2)	GAF Anscochrome D/500 Gafstar Color Aerial Film, Type 7550	2575 (Formerly 48892)	Gafstar	0.10	4	500	90	45	$40 \times 10^{-3}$	AR-2	Color
	GAF 1000 Blue-Insensitive Color		Gafstar	0.10	4	1000	90	55	38	AR-2	Visual color minus the blue-sensitive layer

<sup>a</sup>About 2/5 the speed of Kodabromide Paper No. 2 or Kodak RESISTO Rapid Paper No. 2.

<sup>b</sup>Used in lieu of recommended Kodak processing to obtain gamma ( $\gamma$ ) of 0.8.

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